Deimos-1 Image Improvement via MTF Deconvolution

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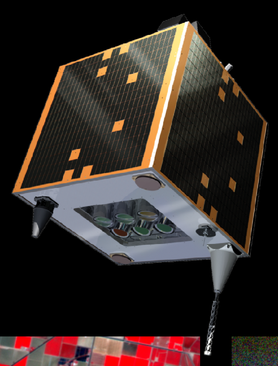
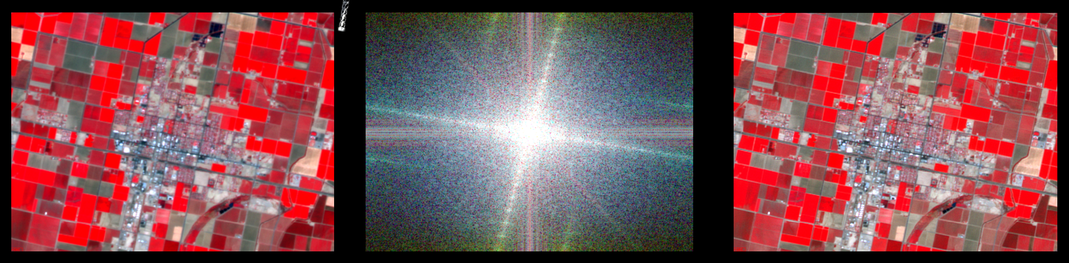
The Deimos-1 Earth Observation System

- **Fully owned and operated by Elecnor Deimos Imaging**
- Member of the Disaster Monitoring Constellation (DMC)
- Launched in July 2009, operational since March 2010
- Sun-Synchronous orbit at 650 km
- Lifetime: 5 years nominal, >7 years expected



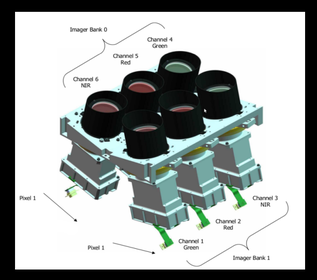
The Satellite

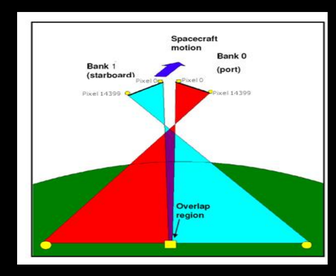
- Built by SSTL (UK)
- Mass: 100 Kg; Nadir-pointing platform
- 8-Gb on-board solid state recorder
- X-, S-band antennas for data transmission, TM/TC



The Payload

- Dual-bank pushbroom CCD, 3 cameras per bank
- **3 bands** matching Landsat's NIR, R, G channels
- **Swath: >620 km**
- **Spatial resolution: 22 m GSD at 10 bits**
- Capacity: >5 million km² par day

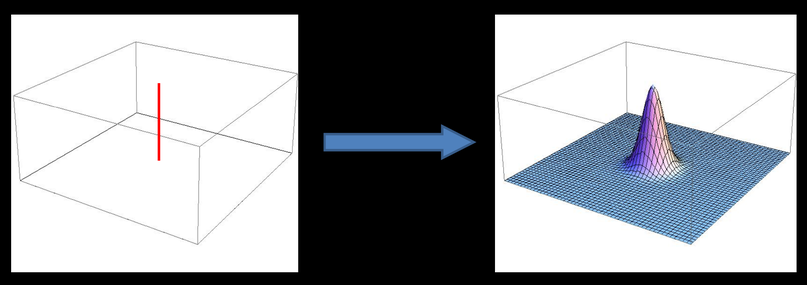




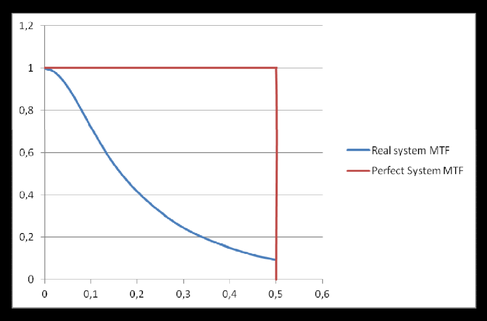
Theory Overview

- As any signal processing system, there is always a distortion between the signal and the measurement. In the case of Deimos-1 payload:
  - Satellite motion
  - Electronics
  - Atmosphere
  - Optical system
  - Viewing geometry
- This distortion causes the footprint of a pixel on the ground to be bigger than the GSD, causing the contamination of the signal by the neighboring area and the loss of image sharpness
- This effect can be theoretically characterized by stimulating the system with an impulse and observing the results

- In an imaging system, the pulse is a light source of infinitesimal dimensions in the spatial domain, and its response is the point spread function (**PSF**)
- The image of a signal can be interpreted as the convolution of the signal and the PSF



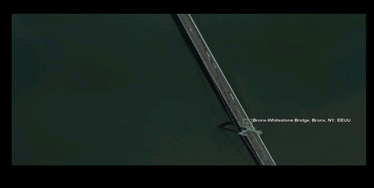
- The optical transfer function (OTF) is the PSF's Fourier transform and the modulation transfer function (**MTF**) is the modulus of the OTF
- The MTF gives the imaging system's performance in terms of spatial frequency and, therefore, in spatial resolution
- In a real system the performance degrades as the frequency increases. Frequency responses beyond Nyquist may cause artifacts



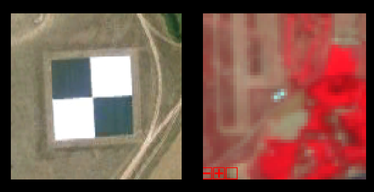
Target Considerations

- The Deimos-1 MTF was measured pre-launch
- Due to launch vibrations, sensor degradation and other factors, it was necessary to measure it again in flight
- Proper targets were selected on-ground to perform the estimation
- Constraints to **in-flight MTF estimation** of Deimos-1:
  - GSD
  - Wide swath
  - Integration time
  - Atmospherical effects & BRDF

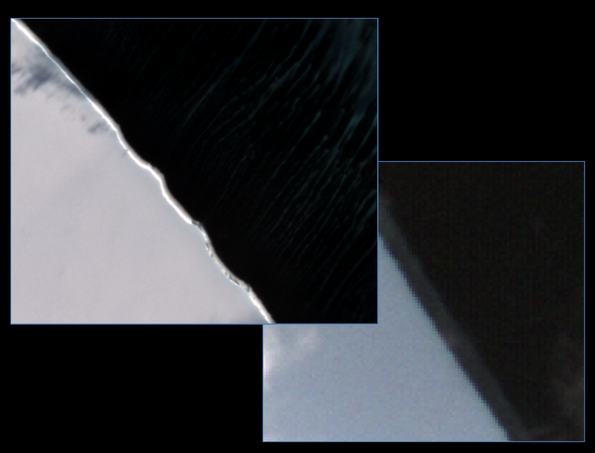
- Point source (Light source)
  - PSF undersampled
- Pulse target (Bridges)
  - Not a true pulse



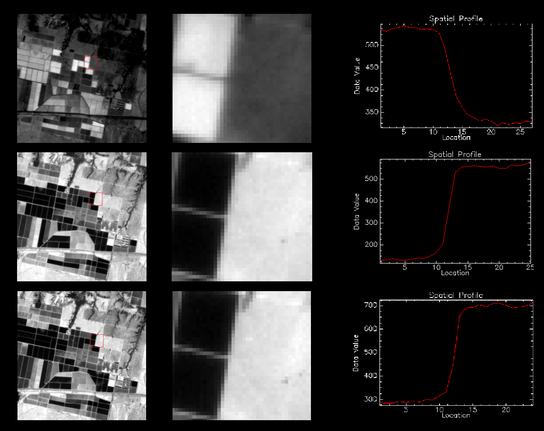
- Artificial calibration targets
  - Too small



- Natural edge targets: Ross ice shelf
  - Sunglint-like effects in the border caused by snow or ice BRDF and the slope
  - Area under a cloud shadow: Diffuse illumination. The border is still not sharp

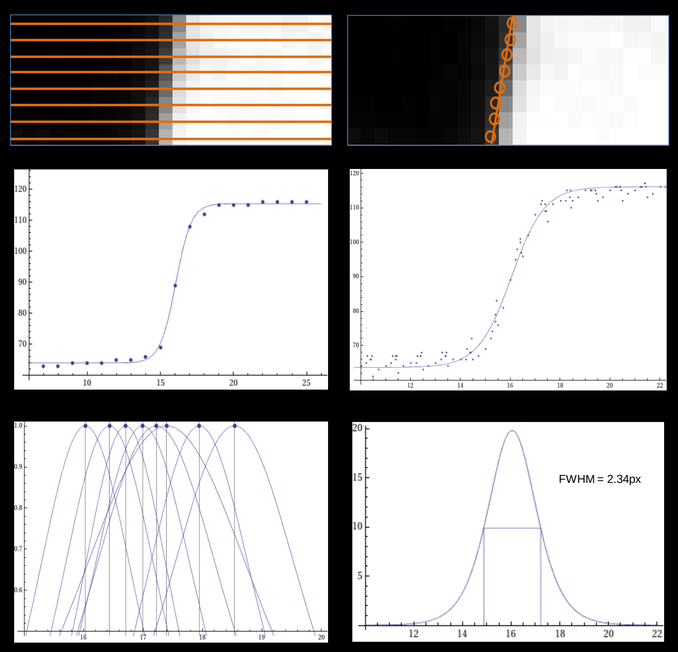


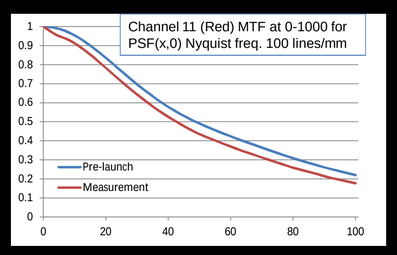
- **Field transitions**
  - High number of targets
  - Sharp edges
  - Enough contrast
  - But: The areas neighboring the edges are not uniform



MTF Estimation

- MTF estimation was performed using the **slanted edge methodology**
- Source data was raw data after PRNU correction
- Fixed integration time for all captures to avoid the motion blur to affect the characterization
- Viewing geometry was taken into account
- The edge is oversampled taking advantage of its tilt
- Information beyond system's Nyquist frequency can be estimated



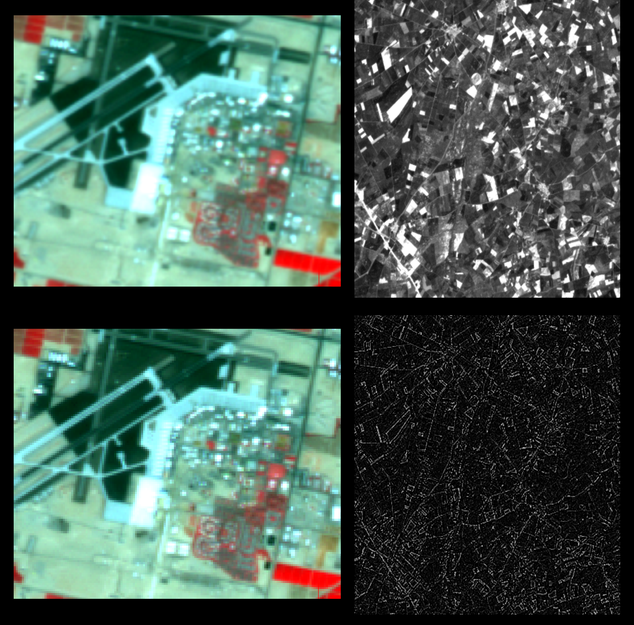


Wiener Deconvolution

- Assumptions:
  - White additive noise, so it is a constant
  - SNR is linear with the signal and has not dependence with the frequency

$$\hat{W}(u,v) = \frac{1}{H(u,v)} \frac{|H(u,v)|^2}{|H(u,v)|^2 + \frac{1}{SNR}}$$

Deconvolution Results



	NIR	Red	Green
Mean difference	0.96%	1.97%	2.00%
Stddev difference	2.19	3.57	3.76

- Uniform areas keep stable
- Variation in non uniform areas

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